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FLIGHT CONDITIONS LEADING TO CLASS A SPATIAL DISORIENTATION MISHAPS IN U.S. AIR FORCE FIGHTER OPERATIONS: FY93-02

A PROJECT REPORT
SUBMITTED TO THE FACULTY OF
THE DEPARTMENT OF PREVENTIVE MEDICINE AND BIOMETRICS OF
THE UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF PULIC HEALTH

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ABSTRACT

Introduction: Over the past 20 years, spatial disorientation (SD) has consistently contributed to 21% of USAF Class A aviation mishaps and 38% of aviation related fatalities. The Air Force Safety Center (ADSC) FY93-02 mishap analysis reported that Class A mishaps resulted in 243 destroyed aircraft, 310 fatalities, and economic losses of $6.23 billion. A human factor analysis of the report's findings revealed SD was the primary cause in 25 of the fighter/attack (FATT) mishaps. This study concerns itself with the factors leading to these FATT SD mishaps. The research completed was conducted in consultation with the Air Force Research Laboratory (AFRL) and the 311 Human System Wing (HSW) at Brooks City-Base in San Antonio, TX. It contributes to the AFSC initiative to meet the Secretary of Defense's charge to reduce preventable mishaps 50% by 2005. AFSC determined the most effective approach to meet this goal was to focus on human factors. The specific aim was to identify SD risk factors by analyzing day, night and instrument meteorological condition (IMC) mishaps that occurred during fighter operations. **Methods:** The data used in this report covers a ten-year period, October 1993 through September 2002 (FY93-02). The data identified SD as either a contributing or causal factor in 25 fighter/attack (FATT) aircraft mishaps among four separate weapons systems (F16, A10, F15E, and F117). Descriptive statistics, incidence density (ID), and rate ratios (RR) were the primary methods of data analysis. All 25 aircraft mishaps were combined in order to calculate ID and make relevant RR comparisons. ID was calculated using number of aircraft mishaps per category (i.e. day, night, and IMC conditions) divided by the total flight-hours in each flight condition. We then calculated rate ratios (RR) per 100,000 flying hours for night using day as the reference category and for IMC using non-IMC as the reference category. **Results:** The descriptive statistics revealed that the 25 Class A SD mishaps resulted in 19 fatalities, 24 aircraft lost, and cost the USAF over $455M. In addition, Type I [unrecognized] SD was present in 23 of the mishaps and in 17 cases there no attempt to recover the aircraft or eject, i.e. controlled flight into terrain (CFIT) occurred. RR was calculated for two comparisons; night vs. day, and IMC vs. non-IMC. The RR night vs. day was 6.62 (95% CI 3.02-14.50) and IMC vs. non-IMC was 2.91 (95% CI 1.22-6.96). These findings reveal there is a seven times greater likelihood of being involved in a Class A fighter mishap due to SD at night when compared to day and three times greater likelihood of a SD mishap while flying IMC when compared to flying Non-IMC missions. **Conclusions:** The primary findings revealed two flight conditions (night and IMC) associated with increased Class A mishaps due to SD. These findings may be incorporated into existing operational risk management and SD training programs (e.g. simulator training), including the development of scenarios to teach recovery skills, and thus helping to mitigate the SD threat.

Keywords: Class A mishap, spatial disorientation, human factors, controlled flight into terrain

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INTRODUCTION/BACKGROUND

During the calendar period January 1993 to December 2002, throughout DoD, Class A mishaps[1] cost the military a total of 750 aircrew lives and $6.8 billion dollars in lost assets. A large portion of these mishaps, approximately 32 percent, were due to Spatial Disorientation (SD), which by itself cost the Department of Defense (DoD) over $2.2 billion dollars. Twenty-one percent of the Class A SD mishaps belonged to the U.S. Air Force (USAF), resulting in economic losses of $1.2 billion dollars, 47 aircraft, and 57 aircrew lives lost (13, 15).

In the FY02 Flight Safety Summary, safety officials reported that USAF averaged one Class A mishap every ten days. There were eleven more Class A Mishaps in FY02 than in FY01 (35 vs. 24). The Class A mishap rate was 1.52 per 100,000 flight-hours (the second highest in ten years) and the cost was the highest in the past ten years ($789M). In addition, 19 aircraft were destroyed and 22 aircrew lost their lives. Twenty-four of the mishaps (68.3%) were classified as operations mishaps (i.e. human error), which includes those due to SD.

In a December 2002 memorandum, General John P. Jumper, Chief of Staff U.S. Air Force stated, "Our Air Force witnessed a sobering safety record in FY02. We lost 113 of our fellow airmen to ground and flight mishaps—up 69% from FY01...With respect to flight safety--35 Class A flight mishaps...That's one flight mishap every 10 days! In addition to the unacceptable loss of life, we destroyed almost a squadron of aircraft worth roughly $820 million. Human factors were cited as the primary cause in two-thirds of our mishaps...We simply cannot tolerate, nor sustain, this level of loss" (15).

These losses are so devastating that Secretary of Defense Donald Rumsfeld stated in his May 2003 memorandum (Appendix C) entitled Reducing Preventable Accidents that "World class organizations do not tolerate preventable accidents" and challenged the U.S. military

[1] Class A – Damage costs of $1,000,000 or more and/or destruction of an aircraft, missile or spacecraft and/or fatality or permanent disability (11).

services to "...reduce the number of mishaps and accident rates by at least 50% in the next two years" (6, 13).

In response, the U.S. Air Force School of Aerospace Medicine Performance Enhancement Division (USAFSAM/FEP) funded a project to produce a Human Systems Information Analysis Center (HSIAC) report "Cost Effective Prevention of Spatial Disorientation – A Joint Services Perspective" (13). This report was based on a comprehensive review of DoD Class A aviation mishaps involving SD with the goal of finding a cost-effective joint service method to combat SD-related aircraft mishaps. Unfortunately, the report was unable to provide a comprehensive review due to data inconsistencies between services, missing data, and the lack of appropriate denominator data for the rate calculations.

This paper seeks to find answers to some of the HSIAC report's questions by identifying factors associated with USAF fighter/attack (FATT) Class A SD mishaps. An overview of SD is required for the reader to be able to understand the research data presented in this paper.

Overview of SD

SD is the term used to describe events/illusions (Appendix D) in flight where the pilot fails to sense or correctly perceive the aircraft's position relative to the horizon. The U.S. Air Force School of Aerospace Medicine's technical report Spatial Orientation in Flight defines an illusion as "a false percept" and an orientational illusion as "a false percept of one's position, attitude, or motion, relative to the plane of the earth's surface" (7). Nearly all pilots, at sometime during their flying career, will experience some form of SD. In most cases the illusion is recognized by the pilot, e.g. a false perception of aircraft bank leading to the development of an illusion called 'the leans'[2] (2, 5, 7, 8, 9, 14).

[2] The leans consists of a false percept of angular displacement about the roll axis (i.e., an illusion of bank) and is frequently associated with a vestibulospinal reflex, appropriate to the false percept, that results in the pilot's actually leaning in the direction of the falsely perceived vertical (6, Appendix D).

Spatial orientation is based on the integration of vestibular, somatosensory[3], auditory, and visual information (1, 5, 7, 8, 12, 14). These systems are designed to give orientational information, or cues, to an individual about his position in relation to the surface of the earth or in relation to other objects in his present environment. Unfortunately, this complex system is not always reliable and is particularly susceptible to false sensations when exposed to parameters outside its design characteristics (i.e. removed from the terrestrial environment and exposed to the flying environment).

There are three types or classes of SD known in the aviation medical and flight safety community. They are Type I [unrecognized], Type II [recognized], and Type III [incapacitating] (1, 5, 7, 8, 10, 11, 12, 13, 14). The three types are described by Previc and Ercoline (12) as:

> **Type I [unrecognized]:** The pilot does not consciously perceive any of the manifestations of SD and is basically oblivious to the SD episode.
>
> **Type II [recognized]:** The pilot consciously perceives some manifestation of SD manifested as either a vestibular or visual conflict.
>
> **Type III [incapacitating]:** The pilot may become incapable of maintaining aircraft control if the vestibular and/or visual conflict is too great, (i.e. extreme disorientation stress).

Unrecognized SD is the form most likely to lead to a Class A mishap. The illusion is often a result of a misperceived visual reference, or cue, which leads the pilot to believe he is oriented to the horizon, when in fact he is not (2, 7, 8, 14). The pilot experiences no disparity between natural and synthetic (instrument-derived) orientational information. He feels that the aircraft is responding well to his control inputs and flies the aircraft in accordance to the false orientational percept (12).

[3] Sensory information or positional feedback from one's body tissues, such as the skin, muscles or tendons (7, Appendix D).

The other types of SD, recognized and incapacitating, are most often the result of vestibular system inputs during aircraft maneuvering. A pilot might experience a conflict between what he "feels" the aircraft is doing and what the instruments show, or between what the instruments show and the outside visual scene. The pilot is aware of the disorientation, but in order to recover from the illusion he has to counter the illusion by returning to wings level flight to reduce the vestibular inputs, concentrate on making the aircraft instruments 'read-right' (i.e. aircraft attitude indicator showing the aircraft in straight and level flight), and/or seek visual meteorological conditions (VMC)[4]. In rare cases, the pilot fails to regain control of his aircraft and must eject from the aircraft to survive. This research paper will focus on determining factors contributing to unrecognized SD -- the most fatal form.

Study Specific Aims

The purpose of the study was to determine factors associated with increased risk of being involved in FATT Class A SD mishap. Factors were analyzed to determine if they played a role in the development of SD, type of illusion experienced, SD type, and mishap outcome. Based on the nature of Class A SD mishaps and associated risk factors, the discussion and conclusion recommend an increased focus on operational risk management (ORM), in-flight and/or simulator SD training scenarios, and a re-evaluation of installing automated ground-collision avoidance (Auto-GCAS) systems in the F16, F15, and F22 aircraft.

MATERIALS AND METHODS

The initial data for this study was obtained from the HSIAC report mishap synopses. The report originally contained 45 USAF Class A SD mishaps for the period of FY92-02. All of the

[4] Weather conditions in which visual flight rules apply; expressed in terms of visibility, ceiling height, and aircraft clearance from clouds along the path of flight. When these criteria do not exist, instrument meteorological conditions prevail and instrument flight rules must be complied with.

mishap synopses used in this paper was generated from original AFSC comprehensive accident investigation reports. The full AFSC accident investigation report is subdivided into several sections. For data analysis purposes, HSIAC only used the following sections from the report: **Tab T** - Investigation, Analysis, Findings, and Recommendations and **Tab Y** - Life Sciences Report.

The HSIAC mishap database included 17 categories:

- Aircraft,
- Date,
- Event Cost (property, aircraft, and injuries),
- Classification Rating (three = major contributor; four = causal),
- Weather (visual or instrument meteorological conditions – IMC[5])
- Terrain (water, desert, mountainous),
- Event (SD type and illusion experienced),
- Time (day or night),
- Experience (flight-hours: total and mishap aircraft),
- SD Experience (narrative of SD factors),
- Outcome (fatal, severe, moderate, minimum, or no injury),
- Narrative (description of the mishap sortie),
- Human-Factors (HF) Related to Mishap,
- Recommendations (by investigation board),
- Night Vision Goggles (NVG type; used in flight – yes or no),
- Aircraft Parameters (speed, angle, aircraft attitude), and
- Ejection (yes or no; within or out of ejection envelope - OE).

IRP Data Analysis

This research study is a secondary data analysis using 25 Class A FATT SD identified by AFSC for the period FY93-02. Due to inconsistencies in the HSIAC report (e.g. two double entries) systematic review of the AFSC Class A, B, C, and E (physiological only) aircraft database was required (17). The intent of the AFSC database review was to ensure all Class A FATT SD mishaps were captured.

The review of the AFSC aircraft mishap database (over 13,000 mishaps) revealed there were a total of 225 Class A FATT mishaps during the ten-year period, of which two additional

[5] Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling; less than minimums specified for VMC.

A10 SD mishaps were identified and confirmed by AFSC. The two A10 SD mishaps were added to the 23 FATT SD mishaps obtained from the HSIAC report -- bringing the total to 25 Class A FATT SD mishap reports used for the data analysis. Table 1 lists mishap factors from the FY93-02 Class A SD FATT database.

Table 1. Description of FY93-02 Class A Spatial Disorientation Mishaps

Date	FY	A/C	Cost	A/C Dest	Ejection	Fatal	Day/Night	IMC/Non-IMC	NVG	Illusion	SD Type	AFSC
12/6/1992	93	A10A	6,768,230	Y	N	1	Day	Non-IMC	N	VIS	1	CFIT
4/28/1993	93	F16C	15,891,217	Y	Y-OE		Day	IMC	N	VIS/VEST	1	UNK
11/8/1993	94	F16C	16,512,034	Y	N	1	Day	Non-IMC	N	VIS/VEST	1	CFIT
11/29/1993	94	F16A	14,355,002	Y	N	1	Day	IMC	N	VEST	1	CFIT
2/14/1994	94	F16C	14,904,637	Y	N		Day	Non-IMC	N	VEST	1	CFIT
9/17/1994	94	A10A	7,061,952	Y	N	1	Day	IMC	N	VEST	1, 2	CFIT
4/18/1995	95	F15E	39,868,722	Y	Y-OE	1	Night	Non-IMC	N	VIS/VEST	1, 2, 3	LOC-I
5/10/1995	95	F117A	51,426,055	Y	N	1	Night	Non-IMC	N	VIS	1	CFIT
10/10/1995	96	A10A	6,787,340	Y	Y		Night	IMC	Y	VIS	2	CFIT
1/7/1997	97	F16A	15,314,597	Y	N	1	Night	IMC	N	VIS	1	CFIT
5/27/1997	97	A10A	7,256,308	Y	N	1	Night	Non-IMC	Y	VEST	1	CFIT
10/22/1997	98	F16B	7,020,940	Y	N	2	Day	Non-IMC	N	VEST	1	MAC
3/23/1998	98	F16C	1,865,329	N	Y		Night	Non-IMC	N	VIS	1	ARC
3/25/1998	98	F16D	24,217,338	Y	Y	1	Night	Non-IMC	Y	VIS/VEST	1, 2	UNK
4/22/1998	98	F16C	22,608,851	Y	N	1	Night	Non-IMC	Y	VEST	1	CFIT
10/21/1998	99	F15E	38,034,391	Y	N	2	Night	Non-IMC	N	VEST	1	CFIT
1/21/1999	99	F16C	20,879,482	Y	Y		Day	Non-IMC	N	VEST	1	CFIT
11/17/1999	00	F16C	20,012,474	Y	Y		Night	Non-IMC	Y	VIS	1	MAC
1/20/2000	00	A10A	11,725,583	Y	N	1	Night	IMC	Y	VEST	1	CFIT
6/12/2001	01	F16C	28,918,452	Y	Y-OE	1	Night	IMC	Y	VEST	1	LOC-I
7/17/2001	01	F16B	15,936,859	Y	N	1	Day	Non-IMC	N	VEST	1	CFIT
9/3/2001	01	A10A	11,725,980	Y	Y		Day	Non-IMC	N	VIS	1	CFIT
1/10/2002	02	F16C	19,414,171	Y	Y		Day	Non-IMC	N	VEST	2	LOC-I
6/27/2002	02	A10A	15,322,006	Y	N	1	Day	Non-IMC	N	VEST	1	CFIT
9/9/2002	02	F16C	21,575,759	Y	N	1	Night	Non-IMC	N	VEST	1	CFIT
25 Total		**15 F16 7 A10 2 F15E 1 F117**	**455,403,709**	**24**	**10**	**19**	**13 Night 12 Day**	**7 IMC 18 Non-IMC**	**7 NVG**	**7 VIS 14 VEST 4 Both**	**23 Type 1 2 Type 2**	**17 CFIT 3 LOC-I 2 MAC 1 ARC 2 UNK**

Method of Data Analysis

Descriptive statistics, incidence density (ID), and rate ratios (RR) were conducted to determine factors associated with increased risk of being involved in a Class A SD mishap. In order to calculate ID and make relevant RR comparisons all 25 mishaps were combined. ID was calculated using number of aircraft mishaps per category (i.e. day, night, and IMC conditions) divided by the total flight-hours in each flight condition.

Flight-Hour Extrapolation Method

USAF Fighter Wings only retain 18 months of flight-hours for night and IMC in a retrievable database at any given time. The Air Force Directorate of Operations, Current Operations Division (HQ USAF/XOOT) was able to provide a total of 19 months (JUN 2002-DEC 2003) of night and IMC flight hour data for the mishap analysis (16). In order to determine RR for each flight condition (i.e. day, night, and IMC) the denominator data (i.e. flight hours flown day, night and IMC) was extrapolated to cover the entire ten-year period of analysis.

This data was meticulously extrapolated to estimate flight-hours in each category (i.e. day, night, IMC, and Non-IMC). The day hours were calculated by subtracting the night hours from the total hours. The amount of Non-IMC flight was calculated as the total number of flying hours minus the IMC flying hours. The data was then used to calculate flight-hour ratios of night to day flying time and Non-IMC to IMC flying time for the period FY93-02. The percentage of night and instrument hours flown over the last ten years has remained roughly constant, so extrapolation of those hours should lead to data that closely approximates the actual risk (16). Detailed flight-hour extrapolation spreadsheets can be found in Appendix E: Extrapolation of Flight-Hour Data.

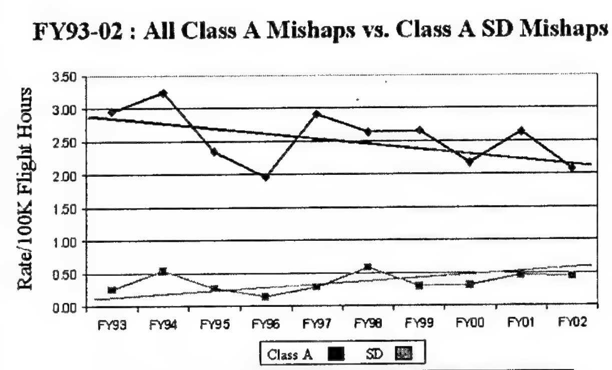
ID and RR Calculation Methods

The estimated flight-hours for night, day, IMC, and Non-IMC was used as denominator data to estimate risk exposure. ID for each exposure condition was calculated by taking the total number of mishaps of each category and dividing it by the total hours of exposure. The resultant incidence densities were used to calculate RR for night vs. day and IMC vs. Non-IMC flight operations.

RESULTS

USAF Class A SD Mishaps

Over the ten-year period FY93-02 the USAF flew a combined total of 6,981,945 flight hours, which yielded an overall Class A rate of 2.71 and a Class A SD rate of 0.36 mishaps per 100,000 total flight-hours (15). Figure 1 is a graphical representation of FY93-02 Class A mishaps (all causes) vs. Class A SD mishaps.



Total Class A Mishaps	Total SD Mishaps	Total Flight Hours	Overall Class A Mishap Rate	Overall SD Mishap Rate
189	25	6981945	2.71	0.36

Figure 1.

The data in the graph was normalized to show that while the overall Class A mishap trend is decreasing, simultaneously the Class A SD mishap trend is increasing. Although this is true

the graph still does not tell the entire story. The use of total flight-hours as the denominator for rate calculations obscures many underlying SD risk factors. By failing to stratify the SD mishap data by category or determining rates based on the appropriate flight-hours the true risk associated with SD was grossly underestimated.

IRP Data Analysis

The goal of this study was to conduct a thorough investigation of all factors to identify flight conditions leading to increased SD risk. This was accomplished by first looking at basic descriptive statistics to identify any trends in the data that revealed factors associated with a greater number of the mishaps. Once these factors were identified ID and RR were calculated for each category to identify which flight conditions were associated with increased risk of developing SD.

Descriptive Statistics

Factors relevant to the mishaps are summarized in Table 2. Each of the factors were closely examined to identify trends in the data and determine if any single factor or combination increased the likelihood of being involved in a Class A SD mishap.

Table 2. Mishap Data by Aircraft and Category

A/C	Cost	A/C Dest	Ejection	Fatal	Day/Night	IMC/Non-IMC	NVG MSHP	Illusion	SD Type	AFSC
15 F16	259,427,142	14	7 Ejections	10	8 Day 7 Night	4 IMC 11 Non-IMC	4 NVG MSHP	3 VIS 9 VEST 3 both	13 Type 1 1 Type 2 1 both	8 CFIT 2 LOC-I 2 MAC 1 ARC 2 UNK
7 A10	666,47,399	7	2	5	4 Day 3 Night	3 IMC 4 Non-IMC	3 NVG MSHP	3 VIS 4 VEST	5 Type 1 1 Type 2 1 both	7 CFIT
2 F15E	779,03,113	2	1	3	2 Night	2 Non-IMC		1 VEST 1 both	1 Type 1 1 Type 1, 2, 3	1 CFIT 1 LOC-I
1 F117	51,426,055	1		1	1 Night	1 Non-IMC		1 VIS	1 Type 1	1 CFIT
25	**455,403,709**	**24 A/C Dest**	**10 Ejections 7 Successful**	**19 Fatal**	**13 Night 12 Day**	**7 IMC 18 Non-IMC**	**7 NVG MSHP**	**7 VIS 14 VEST 4 Both**	**20 Type 1 2 Type 2 2 Type 1 & 2 1 Type 1, 2 , 3**	**17 CFIT 3 LOC-I 2 MAC 1 ARC 2 UNK**

Number and Cost of Mishaps

A total of 25 Class A FATT SD mishaps were entered in to a comprehensive database and analyzed. There were 15 mishaps in the F16, seven in the A10, two in the F15E, and one in the F117. All but one of the 25 mishaps resulted in loss of airframe (Table 2, A/C Dest). The total cost to the USAF was $455M. The total cost for the F16 mishaps was $259M, for the A10 was $67M, the two F15E mishaps generated greatest cost--$78M, and a single F117 cost the USAF $51M.

Mishap Outcomes

The 25 SD mishaps resulted in a total of 19 aircrew fatalities (16 pilots, 2 weapons officers, and one flight photographer). In ten of the mishaps an ejection attempt was initiated. Seven of the ejections were successful, including one out-of-envelope (OE) ejection (i.e. outside the normal parameters for a safe ejection). **There was no attempt to eject in 15 of the mishaps**, one of which the pilot survived the crash albeit with critical injuries.

Day vs. Night

There were essentially equal numbers of mishaps during day and night flying operations (12 vs. 13). Eight of the F16 mishaps occurred during day and seven during the night. Four of the A10 mishaps occurred during day and three during the night. Both the F15E and F117 mishaps occurred during night missions.

IMC vs. Non-IMC

A greater number of mishaps occurred during Non-IMC than during IMC flying operations (18 vs. 7). When examined by aircraft type the F16 had 11 Non-IMC and four IMC mishaps. Five of the A10 mishaps occurred during Non-IMC and two during IMC missions. All of the F15E and F117 mishaps occurred during Non-IMC missions.

Illusion

The majority of SD mishaps were due to vestibular illusions (14 vs. 7). In four of the mishaps the pilot experienced a combination of vestibular and visual illusions. In seven of the mishaps the visual conditions were optimal (i.e. day, VMC flight), yet the pilot still experienced an illusion strong enough to cause an aircraft mishap.

SD Type

There were twenty-three mishaps involving unrecognized SD and only two of the mishaps were recognized SD. Eleven of the unrecognized SD mishaps occurred during the day and twelve at night. **There were eight unrecognized SD mishaps while the pilots were flying missions in ideal visual flight conditions.**

Table 3. SD Type by Aircraft

SD Type	Aircraft Type and Number of Mishaps
Type I	F16 = 13 A10 = 5 F15E = 1 F117 = 1 **Total = 20**
Type II	F16 = 1 A10 = 1 F15E = 1 **Total = 3**
Type III	F15E = 1 **Total = 1**

CFIT

There were **17 controlled flight into terrain (CFIT) mishaps.** This means that in 68% of the mishaps the pilot essentially flew his aircraft into the ground never realizing he was disoriented. In this instance the pilot was more likely to have experienced a vestibular illusion that preceded the CFIT mishap sequence. There were eight CFIT at night, seven during the day, and four during IMC flying operations. Additional CFIT data can be found in Appendix F.

ID and RR Calculations

Analyses of day, night, and IMC conditions were conducted to determine if any of flight conditions were associated with increased risk of developing SD. **This research study is the first to calculate USAF mishaps rates for day, night, and IMC flight conditions using flight-hour specific data.**

Initially there appeared to be no difference between day or night operations (12 vs. 13 mishaps) in relation to the likelihood of developing SD, but a stratified analysis (day vs. night mishaps) using flight-hours specific for each condition revealed an increased risk during night operations (Table 4).

Table 4. Day vs. Night Operations

FY	SD Day	SD Night	Total Flt Hrs	Day Flt Hrs	Night Flt Hrs	ID Day	ID Night	RR
93	2		779109	667130.9	108187.6	0.30		
94	4		742180	635128.9	103387.9	0.63		
95		2	724484	619813.6	101069.7		1.98	
96		1	711407	608298.8	99610.0		1.00	
97		2	689880	589658.7	96874.5		2.06	
98	1	3	685038	585519.4	96239.3	0.17	3.12	18.25
99	1	1	677612	579066.6	95250.4	0.17	1.05	6.08
00		2	647153	553203.1	90824.5		2.20	
01	2	1	647484	553431.9	90851.2	0.36	1.10	3.05
02	2	1	677598	579369.9	94833.1	0.35	1.05	3.05
Total	**12**	**13**	**6981945**	**5970621.8**	**977128.2**	**0.20**	**1.33**	**6.62**

The number of mishaps in each category (i.e. all Class A SD, SD Night, SD Day) is shown in Figure 2. ID was calculated for day and night using category specific flight-hours. ID for night and day were then used to calculate RR (night/day) to determine if there was any increased risk associated with flying at night vs. flying during the day. Figure 3 shows ID for all Class A SD mishaps calculated using total flight-hours and the IDs calculated for day and night using category specific flight-hours. The RR clearly shows an increased risk associated with night (RR 6.62; 95% CI 3.02-14.5) when compared to day.

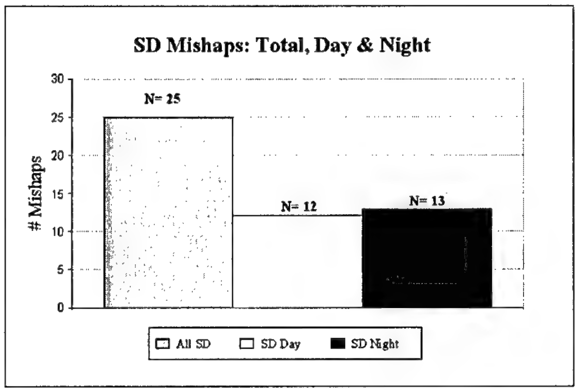


Figure 2.

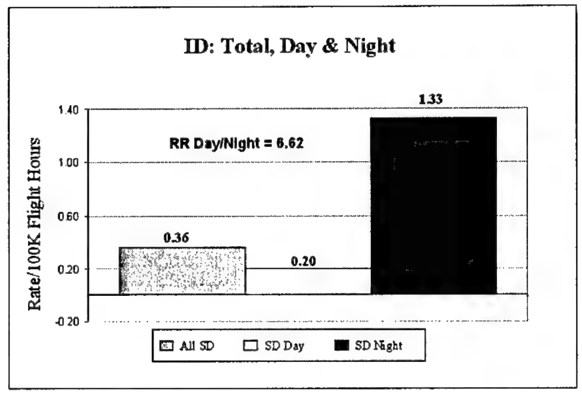


Figure 3.

The IMC vs. Non-IMC analysis showed a slightly greater risk during IMC (RR 2.91; 95% CI 1.22-6.96) when compared to Non-IMC flying operations (Table 5).

Table 5. IMC vs. Non-IMC Operations

FY	SD IMC	SD Non-IMC	Total Flt Hrs	IMC Flt Hrs	Non-IMC Flt Hrs	ID Non-IMC	ID IMC	RR
93		1	779109	91489.4	687619.4	0.15	1.09	7.52
94	2	2	742180	87072.2	655107.8	0.31	2.3	7.52
95		1	724484	84751.3	639732.0	0.31		
96	1		711407	83952.6	627454.4		1.19	
97	1	1	689880	81902.6	607977.4	0.16	1.22	7.45
98		1	685038	81635.4	603402.6	0.66		
99		2	677612	80493.2	597118.8	0.33		
00		1	647153	76914.3	570238.7	0.18	1.30	7.41
01		2	647484	76479.1	571004.9	0.35	1.31	3.73
02		2	677598	79543.9	598054.1	0.50		
Total	**4**	**13**	**6981945**	**824234.0**	**6157710.8**	**0.29**	**0.85**	**2.91**

The number of mishaps in each category (i.e. all Class A SD, IMC SD and Non-IMC SD) is shown in Figure 4. The ID calculation for all Class A SD mishaps and the flight-hour specific ID for IMC and Non-IMC can be found in Figure 5. The RR shows a slightly greater risk associated with IMC (RR 2.91; 95% CI 1.22-6.96) when compared to Non-IMC missions.

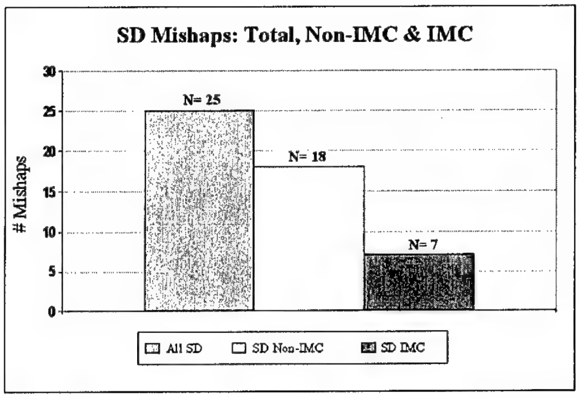


Figure 4.

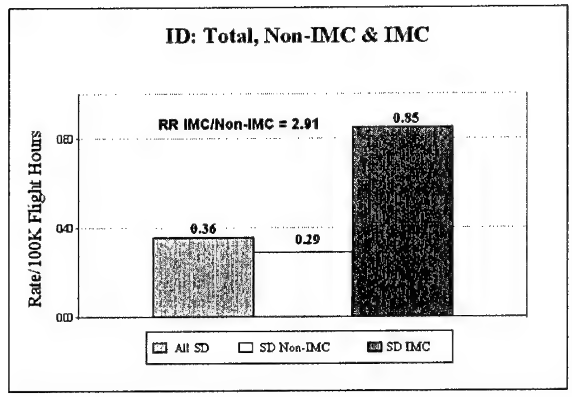


Figure 5.

Results Overview

Thirteen independent variables (Table 1) were analyzed for trends, but none of them were truly "eye-opening". There were three common factors associated with a greater number of the mishaps. Ten mishaps had the following combination of factors -- vestibular illusion, unrecognized SD, and Non-IMC conditions. This is a very simple look at combined factors and cannot be assumed that this combination of factors leads to a greater risk due to the small number of mishaps analyzed.

The most useful information was obtained from the ID and RR data analysis. The stratified analysis revealed two flight conditions (night and IMC) associated with an increased risk of developing SD. These findings can be used to help reduce SD risk by incorporating the information in to existing ORM matrices, human factors (HF) programs (e.g. physiology lectures, CRM) or used to develop in-flight and/or simulator training scenarios.

DISCUSSION

Several recent studies and AFSC reports have analyzed data to determine factors associated with Class A SD mishaps. One report simply looked at numbers of SD mishaps occurring during the day vs. night without taking into account the number of flight-hours flown

during each conditions (Figure 6). Although it is true that more mishaps occur during the day, this is not very useful when analyzing risk. Due to the lack of category specific flight-hours for day and night mishaps a true rate calculation could not be made.

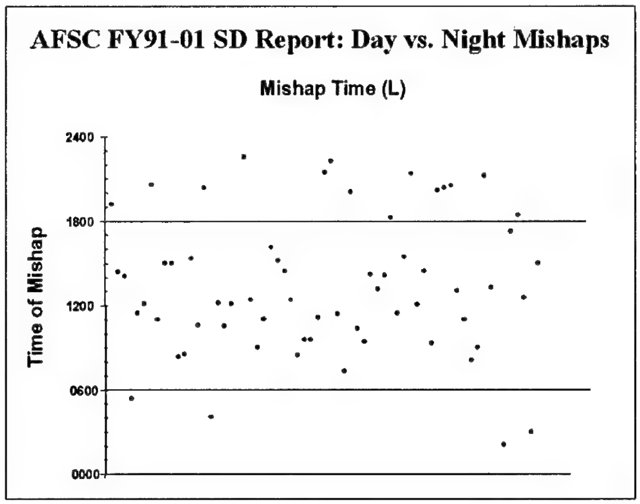


Figure 6.

The most important piece of the puzzle is missing -- the number of flight-hours that are flown during the day vs. during the night. On average, each year, the USAF flies approximately six times more flight-hours during the day than at night. Ignoring this one fact has led to the misconception that the risk of being involved in a SD mishap is greater during day than during night operations. To give credit to the report's author, he did address the fact that at time of publication there was no way to determine if his data showed the true SD risk due to an inability to calculate day, night, and IMC specific rates (3, 4).

IRP Study Purpose

The purpose of this study was to analyze FATT SD mishaps, identify any contributing factors, and determine the risk associated with each exposure condition. In order to accomplish the task, flight-hours for day, night, IMC, and Non-IMC were required to calculate ID and determine RR for Night vs. Day and IMC vs. Non-IMC.

Limitations and Potential Bias

The USAF only retains eighteen months of flight-hours for night and IMC in a retrievable database. Due to this limitation (i.e. available flight-hour data), the data had to be extrapolated to fit the entire ten-year period of analysis. The RR day/night and RR IMC/Non-IMC were based on 19 months of extrapolated flight-hour data -- not actual flight-hour data. Therefore, the possibility of bias exists due to the extrapolation method used for the ID and RR calculations.

Data Entry Errors and Misclassification

There was one area of concern related to the identification of the correct number of Class A FATT SD mishaps. During the review of the HSIAC report two double entries were found and one day mishap was misclassified as a night mishap. These discoveries required a review the entire AFSC aircraft mishap database (over 13,000 mishaps) and several additional HF and SD databases (17) to ensure accuracy of the data.

Unfortunately, the review uncovered numerous inconsistencies between the different AFSC databases. The inconsistencies were due to several factors: investigator classification, changes in mishaps reporting methods, and data entry errors within several of the databases (e.g. AFSC Class A FATT database: 18 double entries and seven mishaps missing data). These errors were reported to the AFSC and corrections were made to prior to my data analysis.

Accordingly, though there were inconsistencies between the databases, it did not significantly affect the analysis conducted in this paper due to the errors having been found and corrected. However, there is also the possibility that the overall SD risk may have been underestimated, due to the exclusion of unknown or undetermined mishaps from the Class A SD database.

CONCLUSIONS

The goal of this study was to identify flight conditions leading to SD mishaps during fighter operations. The most useful aspect of the data analysis related to risk associated with the exposure to day, night and IMC flying operations with respect to the subsequent development SD that resulted in a mishap.

Operational Relevance

The primary findings revealed two flight conditions (night and IMC) associated with increased Class A mishaps due to SD. The information obtained from the data analysis may be useful to both the safety community and training command to help increase awareness of flight conditions leading to the development of SD. Wing and squadron commanders may find the information useful in identifying high risk missions and even control the SD threat by applying appropriate operation risk management (ORM) principles during mission authorization.

Public Health Relevance

The public health relevance of Class A SD mishaps relate the cost burden and loss of life resulting from potentially preventable events. Pinpointing flight operations leading to the development of SD the USAF can effectively counter this flight safety threat. It is believed that spatial disorientation training programs designed specifically to address the limitations of each aircraft type would help to effectively help to reduce SD mishaps (14, 15). **Reducing Class A SD mishaps is not only vital to our military from a cost standpoint; it is the key to preventing unnecessary loss of life among our fighter aircrew population.**

CONTRIBUTORS

CAPT David Johanson, USUHS: Provided mentorship and a wealth of knowledge during the entire academic year. His guidance and editing ensured the IRP project paper was accurate and addressed all issues.

Col Peter Mapes, AFRL/HE: Provided expert guidance on USAF operational issues during the development and completion of the IRP project, practicum and final paper.

LtCol Glenn Hover, USAFSAM/FEP, Mr. William Ercoline and Mr. Rick Evans, AFRL/HEM: Provided the original HSIAC report and data used for my IRP and guidance on my research study hypothesis and methods for analyzing the data.

LtCol Donald White, AFSC and Maj (Ret.) Clark Davenport: Provided expert consultation on SD and how to approach the data analysis undertaken. In addition, they allowed me access to numerous AFSC databases. Without these materials the data cross-check and SD mishap verification could not have been completed.

ACKNOWLEDGEMENTS

I would like to express my gratitude to CAPT David Johanson, Col Peter Mapes, LtCol Glenn Hover, Mr. Rick Evans, Mr. William Ercoline, LtCol Donald White, and Mr. Clark Davenport. I would not have been able to complete this IRP without the valuable time, expertise, and guidance they have given to me throughout the academic year.

I would also like to express my gratitude Col Gary G. Gackstetter, Dr. Tomoko Hooper and Mrs. Cara Olsen. I would not have been able to successfully complete this program, practicum, and independent research project without their assistance, guidance, mentorship, and encouragement.

DISCLAIMER

The opinions expressed in this paper are solely my own and in no way reflect the views of the Uniformed Services University of the Health Sciences, the Air Force Research Laboratory, the Air Force Safety Center, the U.S. Air Force, or the Department of Defense.

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16. Personal Communications with Col. Peter B. Mapes, USAF, MC, CFS; Pilot physician at the Air Force Research Laboratory, Human Effectiveness Directorate (AFRL/HE), Jan 2004.

17. Personal Communications on 15 March 2004 with LtCol Donald White, Special Assistant to Chief Air Force Safety Center, and Mr. Clark J. Davenport, Federal Aviation Administration, Southwest Region Directorate, Fort Worth TX,. Provided materials and granted access to Air Force Safety Center data: FY91-FY00 Human Factors Mishap Database, FY91-FY00 Spatial Disorientation Mishap Database.

APPENDIX A

Institutional Review Board (IRB) Approval of T087VN

UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES
4301 JONES BRIDGE ROAD
BETHESDA, MARYLAND 20814-4799

March 31, 2004

MEMORANDUM FOR CAPT JULIA N. SUNDSTROM BSC, PREVENTIVE MEDICINE AND BIOMETRICS

SUBJECT: Institutional Review Board (IRB) Approval of T087VN for Human Subject Participation

Congratulations! Your minimal risk research protocol T087VN, entitled "***Flight Conditions Leading to Class A Spatial Disorientation Mishaps in U.S. Air Force Fighter Operations,***" was reviewed and approved for execution on March 31, 2004 as an EXEMPT human use study under the provisions of 45 CFR 46.101(b)(4). **This approval expires on March 30, 2007.** You are authorized to enroll up to subjects in this study. This approval will be reported to the full Uniformed Services University IRB scheduled to meet on April 22, 2004.

The specific aims of this study are: 1) to estimate the risk of spatial disorientation in flight during day flight operations; night flight operations; and during instrument weather flight operations; and 2) to identify and describe the factors contributing to spatial disorientation in each flight mishap.

De-identified data from the Human Effectiveness Directorate, Wright-Patterson Air Force Base, will be provided to the PI and was authorized for use on 31 October 2003.

Authorization to conduct this protocol will automatically terminate on March 30, 2007. If you wish to continue with data collection or analysis beyond this date, please submit a USU form 3204A/B (continuing review) to the Office of Research by **January 29, 2007**. Though we will attempt to assist you by sending you a reminder, this reporting requirement is <u>your</u> responsibility.

You are required to submit amendments to this protocol, changes to the informed consent document (if applicable), adverse event reports, and other information pertinent to human research for this project to this office for review. No changes to this protocol may be implemented prior to IRB approval. If you have questions regarding specific issues on your protocol, or questions of a more general nature concerning human participation in research, please contact me at 301-295-9534 or rbienvenu@usuhs.mil.

Robert V. Bienvenu II, Ph.D.
MAJ, MS, USA
Director, Human Research Protections Program
and Executive Secretary, Institutional Review Board

cc: Director, Research Administration
Chair, PMB
File
CAPT Johanson, PMB
Dr. Hooper, PMB

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APPENDIX B

Access to USAF Spatial Disorientation (SD) Mishap Data

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

8 December 2003

MEMORANDUM FOR: Director, Human Subjects Research Protections Program
(ATTN: Dr. Bienvenu)

FROM: AFRL/HE
2610 Seventh Street
Wright-Patterson AFB, OH 45433-7901

SUBJECT: Access to USAF Spatial Disorientation Mishap Data

1. The Air Force Research Laboratory (AFRL), Human Effectiveness Directorate, Wright-Patterson AFB, authorizes Captain Julia N. Sundstrom to use USAF spatial disorientation mishap data for her independent project in partial fulfillment of the requirements for the Master of Public Health degree at the Uniformed Services University of the Health Sciences (USUHS) Department of Preventive Medicine and Biometrics.

2. A portion of the data, sanitized for personal identifiers, has already been provided to Capt Sundstrom via a secure e-mail transmission. She received e-mail authorization for use of this data on 31 October 2003. When available the remaining flight hour data will be transferred and authorized for use in a similar manner.

3. This letter serves as a permanent copy of authorization for Capt Sundstrom to analyze the data in her possession and remaining data on flight hours to determine the relationship of night and instrument conditions on the rate of spatial disorientation mishaps in the USAF.

4. The POC for this memorandum is the undersigned at peter.mapes@wpafb.af.mil, DSN 785-0425.

Peter B. Mapes

PETER B. MAPES, Col, USAF, MC, CFS
AFRL Pilot Physician
Human Effectiveness Directorate

Cc: USUHS/PMB

APPENDIX C

The Secretary of Defense Memorandum

for
Secretaries of the Military Departments
Reducing Preventable Accidents; 19 May 2003

THE SECRETARY OF DEFENSE
1000 DEFENSE PENTAGON
WASHINGTON, DC 20301-1000

May 19, 2003

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTOR, FORCE TRANSFORMATION
DIRECTOR, NET ASSESSMENT
DIRECTOR, PROGRAM ANALYSIS AND EVALUATION
DIRECTORS OF THE DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

SUBJECT: Reducing Preventable Accidents

World-class organizations do not tolerate preventable accidents. Our accident rates have increased recently, and we need to turn this situation around. I challenge all of you to reduce the number of mishaps and accident rates by at least 50% in the next two years. These goals are achievable, and will directly increase our operational readiness. We owe no less to the men and women who defend our Nation.

I have asked the Under Secretary of Defense for Personnel and Readiness to lead a department-wide effort to focus our accident reduction effort. I intend to be updated on our progress routinely. The USD(P&R) will provide detailed instructions in separate correspondence.

APPENDIX D

Glossary: Spatial Disorientation (SD) Illusions

Abbreviated Definitons from:

Gillingham, K. K., Wolfe, J. W. (1985),
Spatial orientation in flight (USAFSAM-TR-85-31),
USAF School of Aerospace Medicine, Brooks AFB, TX.

Glossary: Spatial Disorientation (SD) Illusions

1. **Illusion:** a false percept.

2. **Orientational Illusion:** a false percept of one's position or motion--either linear or angular--relative to the plane of the earth's surface.

3. **Visual Illusions**: involve either the focal mode (central) of visual processing or the ambient mode (peripheral).

   A.Shape Constancy: the natural tendency reshape the image to fit known (stored) visual images by altering the visual angle.

   B.Size Constancy: size constancy relates to smaller images appear to be farther away and larger objects appear to be closer.

   C.Aerial Perspective: any condition that diminishes ambient light level (e.g. fog or haze) can make an object appear farther away as a result of the loss of visual discrimination; vertical visibility under such conditions is much better than the horizontal visibility.

   D.Absent Focal Cues: a decrease in textural cues (e.g. smooth-water or snow-covered terrain) may result in misperception of height above the ground.

   E.Absent Ambient Cues: conditions that require focal vision alone (i.e. using aircraft instruments only) to accomplish what is normally accomplished with both focal and ambient vision (i.e. aircraft instruments and outside visual cues) require cognitive processes to build an orientational percept.

   F.Autokinesis: the apparent movement of a stationary light; a small, dim light seen against a dark background is an ideal stimulus for producing the illusion

   G.Vection Illusions: visually induced perception of self-motion in the spatial environment and can be a sensation of linear self-motion (linear vection) or angular self-motion (angular vection).

   H.Linear Vection Illusion: nearly everyone who drives an automobile has experienced stopped at a stoplight and a presumably stationary vehicle in the adjacent lane creeps forward resulting in a compelling illusion that our own car is creeping backward.

   I. Angular Vection: occurs when peripheral visual cues convey the information that one is rotating.

   J. False Horizons and Surface Planes: when the horizon perceived through ambient vision is not horizontal; e.g. a sloping cloud deck, sloping terrain, lights or rain creating the impression of a horizon at the proximal edge (base) of the rainfall.

4. **Vestibular Illusions:** vestibule-cerebellar axis processes orientation information from the vestibular, visual, and other sensory systems; in the absence of adequate ambient visual orientation cues, the inadequacies of the vestibular and other orienting senses can result in orientational illusions.
   A. **Somatogyral Illusion**: a false sensation of rotation (or absence of rotation) that results from misperceiving the magnitude or direction of an actual rotation; result from the inability of the semicircular ducts to register accurately a prolonged rotation, i.e., sustained angular velocity.
   B. **The Graveyard Spin**: following several turns of a spin the pilot begins to lose the sensation of spinning, when trying to stop the spin; the resulting somatogyral illusion of spinning in the opposite direction makes the pilot reenter the original spin.
   C. **The Graveyard Spiral:** a pilot in a prolonged banked turn loses the sensation of being banked and turning; upon trying to establish a wings-level attitude and stop the turn, the pilot perceives a bank and a turning in the opposite direction from the original banked turn. Unable to tolerate the sensation of making an inappropriate control input, the pilot banks back into the original turn.
   D. **Oculogyral Illusion**: an oculogyral illusion is a false sensation of motion of an object viewed by such a subject; rotatation about a vertical axis at a constant velocity flowed by a sudden stop results not only a somatogyral illusion of rotation in the opposite direction, but also an oculogyral illusion of an object in front moving in the opposite direction.
   E. **Coriolis Illusion:** the vestibular cross-coupling effect, or simply the Coriolis illusion, is another false percept that can result from unusual stimulation of the semicircular duct system; the phenomenon occurs following prolonged rotation in the horizontal plane {the yaw plane) long enough for the sensation of rotation to stop, if the head is then moved into the pitch plane (e.g. 90) a resultant sensation is a tumbling occurs.
   F. **Somatogravic Illusion:** the displacement of otolithic membranes on their maculae by inertial forces so as to signal a false orientation when the resultant gravitoinertial force is perceived as gravitational (and therefore vertical); thus, a somatogravic illusion can be defined as a false sensation of body tilt that results from perceiving as vertical the direction of a nonvertical gravitoinertial force.
   G. **Inversion Illusion:** a type of somatogravic illusion in which the resultant gravitoinertial force vector rotates backward so far as to be pointing away from rather than toward the earth's surface, thus giving the pilot the false sensation of being upside down.
   H. **G-Excess Effect:** this type of somatogravic illusion results from a change in the direction of the net G force, the G-excess effect results from a change in G magnitude; a false or exaggerated sensation of body tilt can occur when the G environment is sustained at greater than 1 G; if a subject sitting upright in a + 2 Gz environment tips the head forward 30° the otolithic membranes will slide forward and produce an additional perceived tilt as great as 90°; good visual orientational cues attenuate the illusory percept.

I. **Oculogravic Illusion:** a visual correlate of the somatogravic illusion and occurs under the same stimulus conditions; deceleration results in a nose-down pitch because of the somatogravic illusion; simultaneously, the pilot observes the instrument panel to move downward, confirming the false sensation of tilting forward.

J. **The Leans:** by far the most common vestibular illusion in flight is the leans; the leans consists of a false percept of angular displacement about the roll axis (i.e., an illusion of bank) and is frequently associated with a vestibule-spinal reflex, appropriate to the false percept, that results in the pilot's actually leaning in the direction of the falsely perceived vertical; pilots frequently get the leans after a prolonged turn, the pilot initially feels the roll into the turn and accurately perceives the banked attitude but as the turn continues, the percept of being in a banked turn dissipates and is replaced by a feeling of flying straight with wings level, upon rolling out of the turn, the pilot's perception is of a banked turn in the opposite direction.

APPENDIX E

Extrapolation of Flight Hour Data

Extrapolation of Flight Hour Data by Aircraft					
FY	MDS	Total Hours	Day Hours	Night Hours	IMC Hours
1993	F-16	433960	374073.5	59886.5	63792.1
1994	F-16	400474	345208.6	55265.4	58869.7
1995	F-16	386429	333101.8	53327.2	56805.1
1996	F-16	374517	322833.7	51683.3	55054.0
1997	F-16	360038	310352.8	49685.2	52925.6
1998	F-16	360245	310531.2	49713.8	52956.0
1999	F-16	352275.0	303661.1	48614.0	51784.4
2000	F-16	343085	295739.3	47345.7	50433.5
2001	F-16	337315	290765.5	46549.5	49585.3
2002	F-16	352779	304095.5	48683.5	51858.5
Total		**3701117.0**	**3190362.9**	**510754.1**	**544064.2**
FY	MDS	Total Hours	Day Hours	Night Hours	IMC Hours
1993	A-10	115064	94697.7	20366.3	20251.3
1994	A-10	119329	98207.8	21121.2	21001.9
1995	A-10	118602	97609.4	20992.6	20874.0
1996	A-10	122953	101190.3	21762.7	21639.7
1997	A-10	125100	102957.3	22142.7	22017.6
1998	A-10	124119	102149.9	21969.1	21844.9
1999	A-10	122629	100923.7	21705.3	21582.7
2000	A-10	111111	91444.4	19666.6	19555.5
2001	A-10	112662	92720.8	19941.2	19828.5
2002	A-10	116960	96258.1	20701.9	20585.0
Total		**1188529.0**	**978159.4**	**210369.6**	**209181.1**
FY	MDS	Total Hours	Day Hours	Night Hours	IMC Hours
1993	F-15	217547	188830.8	24925.7	4411.8
1994	F-15	210241	182489.2	24088.6	4263.7
1995	F-15	206649	179371.3	23677.0	4190.8
1996	F-15	200766	174264.9	23003.0	4071.5
1997	F-15	192081	166726.3	22007.9	3895.4
1998	F-15	188204	163361.1	21563.7	3816.8
1999	F-15	189109	164146.6	21667.4	3835.1
2000	F-15	179372	155694.9	20551.7	3637.7
2001	F-15	183706	159456.8	21048.3	3725.5
2002	F-15	194847	169127.2	22324.8	3951.5
Total		**1962522**	**1703469.1**	**224857.9**	**39799.9**
FY	MDS	Total Hours	Day Hours	Night Hours	IMC Hours
1993	F-117	12538	9528.9	3009.1	3034.2
1994	F-117	12136	9223.4	2912.6	2936.9
1995	F-117	12804	9731.0	3073.0	3098.6
1996	F-117	13171	10010.0	3161.0	3187.4
1997	F-117	12661	9622.4	3038.6	3064.0
1998	F-117	12470	9477.2	2992.8	3017.7
1999	F-117	13599	10335.2	3263.8	3291.0
2000	F-117	13585	10324.6	3260.4	3287.6
2001	F-117	13801	10488.8	3312.2	3339.8
2002	F-117	13012	9889.1	3122.9	3148.9
Total		**129777.0**	**98630.5**	**31146.5**	**31406.0**

Extrapolation of Flight Hour Data by Year

FY	MDS	Total Hours	Day Hours	Night Hours	IMC Hours	Non-IMC Hrs
1993	F-16	433960	374073.5	59886.5	63792.1	370167.9
1993	A-10	115064	94697.7	20366.3	20251.3	94812.7
1993	F-15	217547	188830.8	24925.7	4411.8	213135.2
1993	F-117	12538	9528.9	3009.1	3034.2	9503.8
1994	F-16	400474	345208.6	55265.4	58869.7	341604.3
1994	A-10	119329	98207.8	21121.2	21001.9	98327.1
1994	F-15	210241	182489.2	24088.6	4263.7	205977.3
1994	F-117	12136	9223.4	2912.6	2936.9	9199.1
1995	F-16	386429	333101.8	53327.2	56805.1	329623.9
1995	A-10	118602	97609.4	20992.6	20874.0	97728.0
1995	F-15	206649	170072.1	22449.5	3973.6	202675.4
1995	F-117	12804	9731.0	3073.0	3098.6	9705.4
1996	F-16	374517	322833.7	51683.3	55054.0	319463.0
1996	A-10	122953	101190.3	21762.7	21639.7	101313.3
1996	F-15	200766	174264.9	23003.0	4071.5	196694.5
1996	F-117	13171	10010.0	3161.0	3187.4	9983.6
1997	F-16	360038	310352.8	49685.2	52925.6	307112.4
1997	A-10	125100	102957.3	22142.7	22017.6	103082.4
1997	F-15	192081	166726.3	22007.9	3895.4	188185.6
1997	F-117	12661	9622.4	3038.6	3064.0	9597.0
1998	F-16	360245	310531.2	49713.8	52956.0	307289.0
1998	A-10	124119	102149.9	21969.1	21844.9	102274.1
1998	F-15	188204	163361.1	21563.7	3816.8	184387.2
1998	F-117	12470	9477.2	2992.8	3017.7	9452.3
1999	F-16	352275	303661.1	48614.0	51784.4	300490.6
1999	A-10	122629	100923.7	21705.3	21582.7	101046.3
1999	F-15	189109	164146.6	21667.4	3835.1	185273.9
1999	F-117	13599	10335.2	3263.8	3291.0	10308.0
2000	F-16	343085	295739.3	47345.7	50433.5	292651.5
2000	A-10	111111	91444.4	19666.6	19555.5	91555.5
2000	F-15	179372	155694.9	20551.7	3637.7	175734.3
2000	F-117	13585	10324.6	3260.4	3287.6	10297.4
2001	F-16	337315	290765.5	46549.5	49585.3	287729.7
2001	A-10	112662	92720.8	19941.2	19828.5	92833.5
2001	F-15	183706	159456.8	21048.3	3725.5	179980.5
2001	F-117	13801	10488.8	3312.2	3339.8	10461.2
2002	F-16	352779	304095.5	48683.5	51858.5	300920.5
2002	A-10	116960	96258.1	20701.9	20585.0	96375.0
2002	F-15	194847	169127.2	22324.8	3951.5	190895.5
2002	F-117	13012	9889.1	3122.9	3148.9	9863.1
Total Hrs		**6981945**	**5970621.8**	**977128.2**	**824234**	**615770.8**

APPENDIX F

Controlled Flight into Terrain (CFIT) Data Analysis

Controlled Flight into Terrain (CFIT) Data Analysis

A/C	FY	Day vs. Night	IMC vs. Non-IMC	Fatal	Cost	F16 Cost	A10 Cost	F15 Cost	F117 Cost
A10A	93	Day	Non-IMC	1	6,768,230		6,768,230		
F16C	94	Day	Non-IMC	1	16,512,034	16,512,034			
F16A	94	Day	IMC	1	14,355,002	14,355,002			
F16C	94	Day	Non-IMC		14,904,637	14,904,637			
A10A	94	Day	IMC	1	7,061,952		7,061,952		
F117A	95	Night	Non-IMC	1	51,426,055				51,426,055
A10A	96	Night	IMC		6,787,340		6,787,340		
F16A	97	Night	IMC	1	15,314,597	15,314,597			
A10A	97	Night	Non-IMC	1	7,256,308		7,256,308		
F16C	98	Night	Non-IMC	1	22,608,851	22,608,851			
F15E	99	Night	Non-IMC	2	38,034,391			38,034,391	
F16C	99	Day	Non-IMC		20,879,482	20,879,482			
A10A	00	Night	Non-IMC	1	11,725,583		11,725,583		
F16B	01	Day	Non-IMC	1	15,936,859	15,936,859			
A10A	01	Day	Non-IMC		11,725,980		11,725,980		
A10A	02	Day	Non-IMC	1	15,322,006		15,322,006		
F16C	02	Night	Non-IMC	1	21,575,759	21,575,759			
17		**9 Day** **8 Night**	**13 Non-IMC** **4 IMC**	**14**	**298,195,066**	**142,087,221**	**66,647,399**	**38,034,391**	**51,426,055**

Night: 8 of the 13 Night SD mishaps (61.5%) were CFIT
8 of the 17 CFIT mishaps (47%) occurred during night ops

Day: 9 of the 12 Day SD mishaps (75%) were CFIT
9 of the 17 CFIT mishaps (53%) occurred during day ops

IMC: 4 of the 7 IMC SD mishaps (57%) were CFIT
4 of the 17 CFIT mishaps (24%) occurred during IMC ops

Non-IMC: 13 of the 18 IMC SD mishaps (72%) were CFIT
13 of the 17 CFIT mishaps (76%) occurred during Non-IMC ops

APPENDIX G

Table and Figure Acronym List

Table and Figure Acronym List

A/C	Aircraft
A/C Dest	Aircraft Destroyed
AFSC	Air Force Safety Center
FY	Fiscal Year
IMC	Instrument Meteorological Conditions
MSHP	Mishap
NVG	Night Vision Goggles
NVG MSHP	Night Vision Goggle Mishap
VEST	Vestibular Illusion
VIS	Visual illusion
VMC	Visual Meteorological Conditions
VIS/VEST	Visual and Vestibular Illusions